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Status and outlook of solar energy use in Pakistan

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Abstract

Pakistan is an energy deficient country, where a large fraction of the population still does not have access to modern day energy services such as electricity. This is due to very limited fossil fuel resources and poor economy, which restrains the import of fossil fuels on a large scale. To overcome energy shortage, Pakistan needs to develop its indigenous energy resources like hydropower, solar and wind. Pakistan lies in an area of one of the highest solar insolation in the world. This vast potential can be exploited to produce electricity, which could be provided to off-grid communities in the northern hilly areas and the southern and western deserts. Applications other than electricity production such as solar water heaters and solar cookers also have vast applications. All this will help in both reducing the import of fossil fuels and dependency of people on fuel wood, which in turn will provide some respite for the dwindling forest reserves of Pakistan. Accordingly, the status and outlook of solar energy use in Pakistan is discussed in this paper. In addition, the role of R&D organizations in the promotion of solar energy technologies in Pakistan is also presented including a description of some proposed projects. It is concluded that the current infrastructure has not been able to advance the status of solar energy of Pakistan. Significant efforts are needed to effectively utilize this cheap renewable energy source.

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Contents

1. Introduction

Energy consumption is an index of prosperity and standard of living of people in a country. As a result of technological and industrial development, the demand of energy is rapidly increasing. Pakistan will be facing the acute challenge of energy deficit in the near future and even today the primary energy supplies are not enough to meet the present demand. This is forcing the government to give serious thoughts to the development of indigenous alternative and renewable energy resources. In addition, environmental friendly renewable energy sources need to be developed and popularized to achieve the goal of sustainable development. Other incentives for promotion of such energy technologies, particularly in the developing

countries like Pakistan, are clean environment, energy independence, new employment opportunities and improvement of living conditions in rural areas resulting in reduction in mass migration to urban areas. In this paper, the status and outlook of solar energy use in Pakistan are presented. The following sections describe the geography of Pakistan, prevailing energy situation and the current use of solar energy technologies, along with institutional infrastructure followed by sections on policy and planning.

2. Geographic profile of Pakistan

Pakistan is situated between latitude 24 and 37 degrees North and longitude 62 and 75 degrees East. The country borders India in the east, Iran on the west, China in the north, Afghanistan in the north-west and the Arabian Sea on the south. A country map is shown in Fig. 1. The total area of Pakistan is 8,03,950 sq. km., which includes Federally Administered Tribal and Northern Areas (FATA and FANA). The country is divided into four provinces namely North-West Frontier Province (NWFP), Punjab, Sindh, and Baluchistan. The great mountain ranges of the Himalayas, the Karakorams and the Hindukush form Pakistan's northern highlands of NWFP and the Northern Areas. Punjab province is a mostly flat, alluvial plain with five major rivers dominating the upper region eventually joining the Indus River flowing south to the Arabian Sea. Sindh is bounded on the east by the Thar Desert and the Rann of Kutch and on the west by the Kirthar range and the Baluchistan Plateau is predominantly an arid tableland, encircled by dry mountains [1].

3. Current energy situation

Fig. 2 shows a graphical representation of Pakistan's primary energy supplies. Pakistan's energy mix is highly dependent on oil, liquid petroleum gas (LPG) and natural gas that account for 85.2% of the total primary energy supplies of 44.465 million tonnes of oil equivalent (MTOE). Coal contributes only 4.5% to the total supplies, while nuclear energy has a share of 1.1% and the remaining 9.2% is supplied by hydroelectricity [2].

In 2000, Pakistan produced about 56,000 barrels of crude oil per day meeting nearly 15% of the domestic oil demand. The remaining 85% was imported from the Middle East with a cost of US$2.4 billion, which is equal to 30% of the country's total export earnings [3]. The high dependence on oil imports has a major impact on national economy. The known recoverable reserves of crude oil are 33 million tonnes and at the current production level of 2.8 million tonnes per year, these will finish in about 11.4 years. The gas reserves are in relatively better position. The presently known reserves of 581 billion cubic meters should last about 26.4 years at the on-going production rate of 22 billion cubic meters per year. The coal reserves are in large quantity (2265 million tonnes). However, domestic coal is not utilized

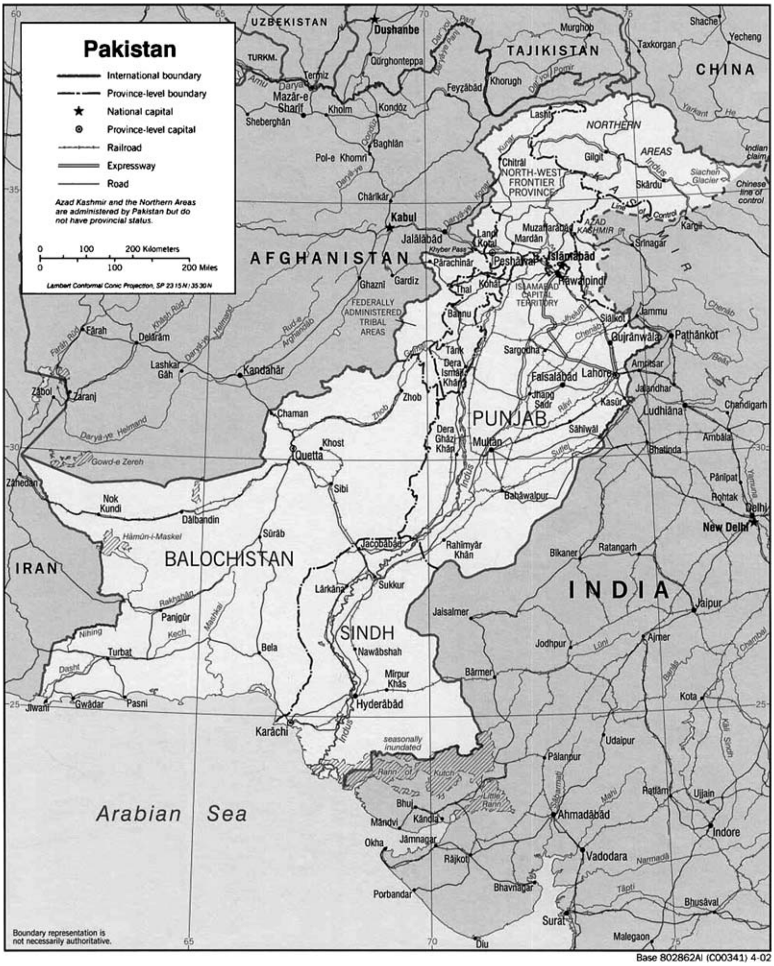


Fig. 1. Map of Pakistan (Courtesy of The General Libraries, The University of Texas at Austin).

much in Pakistan due to its poor quality in terms of heating value and high amounts of sulfur. Therefore, the rate of domestic production of coal is only 3.3 million tonnes per year [4].

4. The solar option

At present, coal, oil and gas are the main sources of energy globally. The total reserves of all these sources are limited and, being non-renewable, will run out eventually. The energy demand will further increase because of the industrial development and the rapid increase in population. Nuclear power was believed to be the

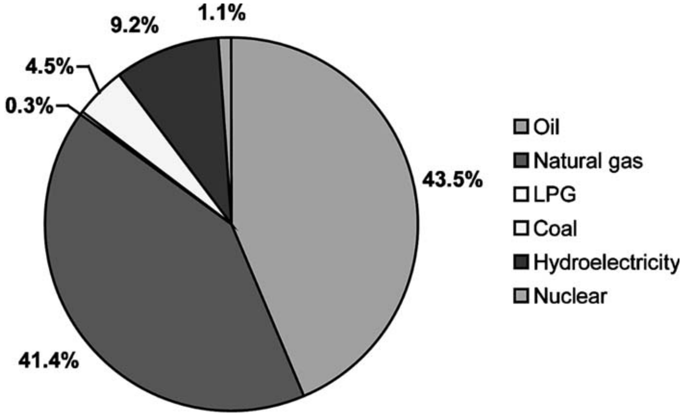


Fig. 2. Primary energy supplies by source. *Source*: Pakistan Energy Yearbook 2001.

replacement of fossil fuels in its early days but so far this hope has not materialized due to proliferation concerns and problems with radioactive waste management. The ever-increasing threat to the environment due to the burning of fossil fuels is another challenge to be taken seriously. Therefore, there is now a worldwide growing interest in alternative and renewable energy resources. There are quite a number of renewable energy sources, but the resources that are technologically viable and have prospects to be exploited commercially in Pakistan include micro-hydel, bio-energy, wind and solar energy. Among all these renewable energy sources, solar energy is by far the most abundant, widely spread and clean source, as presented below.

5. Solar energy potential in Pakistan

Pakistan, being in the sun belt, is ideally located to take advantage of solar energy technologies. This energy source is widely distributed and abundantly available in the country. Fig. 3 shows a solar insolation map of Pakistan. The mean global irradiation falling on horizontal surface in Pakistan is about 200–250 watt per m^2 in a day with about 1500–3000 sunshine hours in a year. The south-western province of Baluchistan is particularly rich in solar energy. It has an average daily global insolation of 19–20 MJ/m^2 a day (1.93–2.03 MWh per m^2 in a year) with annual mean sunshine duration of 8–8.5 h. Such conditions are ideal for photovoltaics (PV) and other solar energy applications [5]. The Energy Information Administration [6] describes the daily solar energy potential for Pakistan as 5.3 KWh per m^2 (1.93 MWh per m^2 annually), which is in accordance with the aforementioned values.

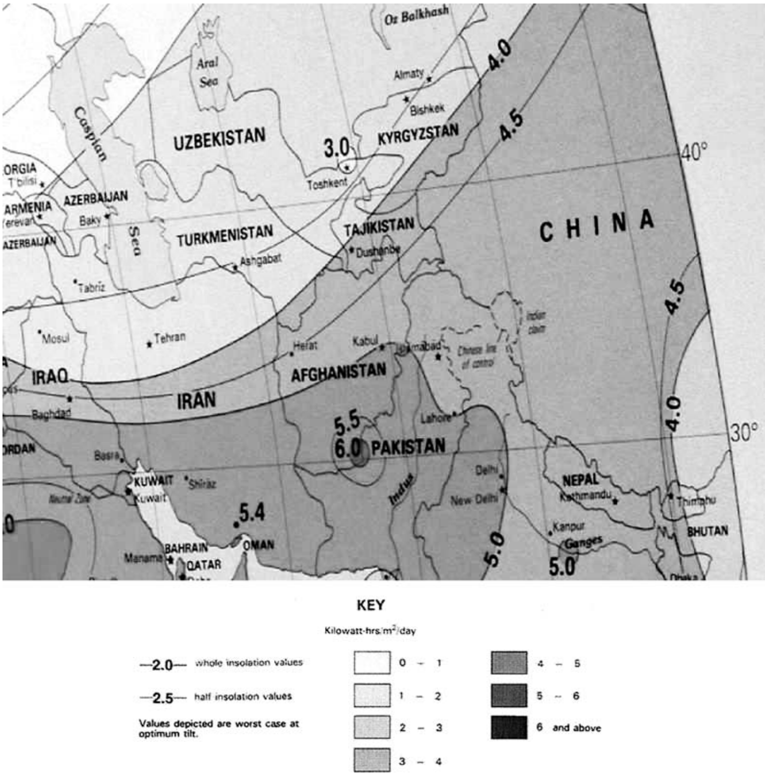


Fig. 3. Solar insolation map of Pakistan (Courtesy of the Advanced Energy Group, http://www.solar4power.com).

6. Current solar energy applications in Pakistan

Both photovoltaics and solar thermal technologies have the potential for vast application in Pakistan, though the scale of utilization so far has been smaller. Solar energy has been utilized in Pakistan for about a quarter of a century. The different application areas, mainly photovoltaics and solar thermal applications, are summarized here.

6.1. Photovoltaics

The best way to utilize solar energy is through photovoltaics, which convert the sun energy directly into electricity—undoubtedly the most convenient form of energy. Photovoltaic technology is particularly suitable for small power requirements and remote area applications. The provinces of Sindh and Baluchistan, and the Thar Desert are specially suited for the utilization of solar energy through photovoltaics. Baluchistan, the largest province of Pakistan area-wise, has a population density of just 21 persons per square kilometer [7], with 77% of the

population living in rural areas. About 90% of the villages are yet to be electrified. These villages are separated by large distances with absolutely no approach roads. The houses are mostly 'kacha' hut type with walls and roofs made with a combination of mud and straw. Light is the only requirement for these houses. Most of the houses consist of only one room. The electric requirement for each house varies from 50 to 100 W maximum. Transmission lines are very expensive to build in these areas and there is only a remote possibility of grid connection in the near future. Also, the extension of grid lines for such small power requirements is very uneconomical. Local power generation is a possible solution to these problems. When considering diesel generators, transportation of fuel to such remote areas and maintenance are again a costly proposition. Therefore, solar energy looks like the best (and only) option for these areas.

In the early 1980s, eighteen PV stations were set up by the government in different parts of the country for village electrification, with an installed capacity of nearly 440 kW. However, because of lack of technical know-how and follow up, these systems have not performed as required. Currently solar technology is being used in Pakistan for stand alone rural telephone exchanges, highway emergency telephones, cathodic protection, refrigeration for vaccine and medicines in hospitals etc. The Public Health Department has installed about 20 solar water pumps for drinking purposes in different parts of Baluchistan [5]. The mountain areas of Hindu Kush-Hamalayas (HKH) region, located in the northern and western part of Pakistan, are blessed with plenty of sunshine with daily average solar radiation of 4–6 kWh/m^2. About seven solar stations were installed in the late 1980s for village lighting by different agencies in various parts of HKH region. These systems, with a total capacity of 234 kW, are not in operation nowadays because of maintenance problems [8].

The US Energy Information Administration reported in May 2000 [9] that in order to provide electricity to rural areas that would otherwise not have electricity in the foreseeable future because they were either too remote and/or too expensive to connect to the national grid, the Government of Pakistan was turning to solar power. Pakistan signed a $50 million memorandum of understanding with World-Water, an American company, to assemble and manufacture plants to build solar modules and electronic controls to power water pumps and electric accessories.

Empower Consultants of New Zealand, a Wellington-based renewable energy specialist, is working to bring affordable electricity to poor villagers in the harsh deserts of Gawadar area in Baluchistan province. The project commenced in February 2001 and by June 2002 the team had completed a feasibility study and detailed design stage and equipment purchasing is now underway. The 'prime mover' for the project is centered on a 6 kW solar PV array, with a 10 kW inverter, large capacity (90 kWh) battery bank, 100 Amp 120 VDC solar charge controller and 7 kW backup diesel generator forming the backbone of the system. The system is expected to provide approximately 30 kWh per day to the community—or more depending on diesel backup system usage [10].

Both the private and public sectors are playing their roles in the popularization and upgrading of photovoltaic activities in the country. A number of companies

are not only involved in trading photovoltaic products and appliances, but also in manufacturing different components of PV systems. They are selling PV modules, batteries, regulators, invertors, as well as practical low power gadgets for load shedding such as photovoltaic lamps, battery chargers, garden lights etc. The prominent one among these companies is SIEMENS Pakistan, which has installed many stand alone solar power systems in the country [11]. On the Lahore-Islamabad Motorway, the company has supplied and installed power supply systems for a number of microwave-link repeater stations in the Salt Range area and more than 350 emergency call boxes [12]. Details about the companies doing solar energy related business in Pakistan can be found elsewhere [13,14].

6.2. Solar thermal applications

There are a large number of applications in which solar energy can be utilized directly by exploiting its heat characteristics. Such technologies are comparatively simple, relatively low cost and easy to adopt. The applications include cooking, heating and cooling of buildings, generation of high temperature steam, heating water for domestic and industrial applications, and drying agricultural products under controlled temperatures. A brief description of these applications in Pakistan is provided here.

6.2.1. Solar water heaters

Solar water heating technology is quite mature but its use in Pakistan has been quite limited so far mainly because of higher capital cost of solar water heater as compared with conventional ones operating on natural gas. A number of public sector organizations are actively working on the development of low cost solar water heaters that have now started gaining popularity particularly in the northern mountainous regions due to cold weather and limited and difficult supply of natural gas in these areas. With the electricity and natural gas prices registering sharp increases, the use of solar water heaters is bound to increase. The production and commercialization of such heaters has already been started in the private sector [5].

6.2.2. Solar cooker

A number of public sector organizations have worked in the past and are still working on the development of low cost and efficient designs of both box and concentrator type solar cookers. Non-governmental organizations are also active in this field and have supplied a number of such cookers to camps of Afghan refugees. The Pakistan Council for Renewable Energy Technologies (PCRET), which is later described in this paper, routinely organizes training workshops on the use and maintenance of such devices [5]. The number of solar cookers in use in HKH region of Pakistan is more than 2000, but it is still far less than that being used in similar regions in China (60,000) and India (about 14,500) [15]. Pakistan needs to popularize solar cooker use in the HKH region in order to reduce the use of precious forest resources as fuel wood.

6.2.3. Solar dryers

Solar energy can be utilized very effectively in drying agriculture products using solar dryers, and good quality products can be obtained at much less cost due to savings in cost of electricity or other heating fuels that would have been used otherwise for the same purpose. Due to the lack of logistics and basic infrastructure in the northern mountainous regions of Gilgit and Sakardu, etc., tons of fruit like apricots used to be wasted every year. Solar dryers are now being used to dry large quantities of such fruit and transport and sell them later in the urban market, resulting in a positive effect on the economy of this area. NGOs are actively working to popularize the use of such dryers. Solar dryers could be equally effectively used in the provinces of Punjab and Sindh to dry agriculture products for better market value and generating local employment [5].

6.2.4. Solar desalination

The unavailability of drinkable water in large parts of Baluchistan, Sindh and southern Punjab is a critical issue. Underground water exists, but it is highly saline due to the presence of mainly sodium chloride. Saline water is not only unfit for washing and cleaning but also causes many diseases such as hypertension. Solar energy can very effectively and economically be used to convert this available saline water into potable water. The solar desalination technology is simple, low cost and low-tech, and therefore, it can easily be adopted by local people. Furthermore, solar desalinated water is also free from bacteria, which is killed during the process. Two plants consisting of 240 stills each with a capacity to clean 6000 gallons of seawater per day have been installed at Gawader in the Baluchistan province. This project has been very successful and helped changing the life styles of the local population. A number of such schemes are under active consideration by local governments in Baluchistan and Thar [5].

7. Institutional infrastructure

In Pakistan, all the R&D work is carried out by public sector organizations due to the lack of such capabilities in the private sector. These public bodies, who are wholly or partly engaged in research in the field of renewable energy technologies in Pakistan and their applications, are described below.

7.1. Pakistan Council for Renewable Energy Technologies

The Pakistan Council for Renewable Energy Technologies (PCRET) was established in 2001 by merging the National Institute of Silicon Technology (NIST) and the Pakistan Council for Appropriate Technologies (PCAT). This was done to achieve a better coordination of activities and to avoid duplication of research. The council has its head office in Islamabad, the federal capital, and four regional/field offices in the provincial capitals i.e. Peshawar, Lahore, Karachi and Quetta. PCRET has been assigned the responsibility to coordinate research and development activities on renewable energy technologies in the country, particularly in the

areas of microhydel power plants, biogas, fuel saving technologies, solar thermal appliances, photovoltaics and wind energy [16]. PCRET is a relatively newborn entity and is still in the reorganization phase, and therefore, the activities of its predecessors, namely the National Institute of Silicon Technology and the Pakistan Council of Appropriate Technology, are discussed here.

7.1.1. National Institute of Silicon Technology

Established in 1981, NIST was devoted to the research, development and popularization of solar energy in general and photovoltaics in particular in the country. The Institute was mainly concentrating on the complete spectrum of mono crystalline silicon solar cell technologies. It had facilities to grow silicon single crystals, saw ingots into wafers, process wafers to fabricate solar cells, laminate photovoltaic modules and conduct all different types of test and measurement of cells, modules and systems. Lately, the research was focused on the development of low cost processes by using comparatively cheaper and indigenously available materials. NIST also developed systems such as solar lanterns, street and garden solar lights, cells and battery chargers, light home systems, etc. The Institute was also working actively on the development of low cost and efficient solar thermal appliances such as solar water heaters, solar cookers, solar dryers, solar desalination plants etc. The NIST, located in Islamabad, had provided an opportunity to see a large number of different but closely related solar technologies at one place. The Institute has earned an international reputation and has developed linkages with a number of international organizations [5]. Furthermore, NIST also developed renewable energy proposals that are described later in this paper.

7.1.2. Pakistan Council of Appropriate Technology

The council was established in 1975 in Islamabad with the main objectives of promoting appropriate technologies in the country. Major areas in which PCAT was involved pertain to food, energy, health and habitation, including potable water, sanitation, and small-scale income-generating trades. PCAT worked in the field of renewable energy, and particularly in the installation of mini hydropower plants, biogas plants, solar cookers, harnessing wind energy for water pumping, and energy efficient cooking stoves [5].

7.2. Solar Energy Research Centre

The Solar Energy Research Centre, located in the southern city of Hyderabad, is a mono-functional unit of the Pakistan Council of Scientific and Industrial Research under the Ministry of Science and Technology [17]. Its research and development program is focused on the utilization of adoptive and adaptive methodology for exploiting solar energy sources. Most of its research is undertaken in the fields of solar thermal applications, including power generation, solar desalination, solar air-conditioning and heating.

7.3. Academic

Although there is not a well-established research culture in Pakistani universities in the field of renewable energy, still a small number of university departments actively conduct research in the field of solar thermal technologies. For instance: (i) the Electrical and Mechanical Engineering College of the National University of Sciences and Technology in Rawalpindi, is active in solar thermal power generation, solar thermal power generation device (sterling engine), and space heating/cooling; (ii) the Institute of Environmental Studies of the Ghulam Ishaq Khan (GIK) Institute of Engineering Sciences and Technology in Topi, NWFP, is involved in solar thermal device testing; and (iii) the Mechanical Engineering Department of the University of Engineering and Technology, Lahore, is engaged in research in solar radiation and other solar thermal activities [5].

7.4. National Commission for Alternative Energy

The national daily Dawn (14 June 2001) reported [18] that the Government would soon establish a National Commission for Alternative Energy (NCAE) to introduce and promote various technologies in the country, and Dr. Nasim A. Khan would be the first chairman of this commission. In addition, the year 2002 was declared as the year of solar technology. Dr. Khan also heads the Pakistan chapter of International Solar Energy Society (ISES) [19]. Dawn further reported on 24 October 2002 that NCAE and Institute of Renewable Energy Technologies would be established in the near future [20]. Due to administrative delays, the formal notification for setting up these organizations is yet to be issued by the government.

8. Renewable energy project proposals

The National Institute of Silicon Technology (NIST), described earlier in this paper, served as the national focal point to develop renewable energy project proposals and to prepare Pakistan's participation in the World Solar Summit that took place in Harare, Zimbabwe on September 16–18, 1996. The project proposals are listed in Table 1 along with brief descriptions, with the majority of these projects (12 out of 16) being based on the use of solar energy technologies. For individual projects, the duration varies from 1.5 to 6 years, while the estimated cost is between 0.02 to 46 million US dollars. The first twelve projects mentioned in the table are on the UNESCO list of National High Priority Projects.

In spite of the fact that recognition of the importance of these energy technologies exists in government circles, the country is not in a position financially to provide grants for these activities. Therefore, the support of international funding agencies is essential at this stage to help promote wider use of these technologies in the country. These projects, if implemented, will not only generate the market to boost the industrial and commercial activities, but also act as centers for education, training and dissemination of technology [5].

Table 1
Renewable energy project proposals

No.	Project Title	Period (Years)	Cost US$ million
1	Energy self sufficient model house	5	0.27
2	Rural area electrification	5	10.00
3	Solar desalination pilot project	6	5.00
4	Community solar dryers for drying grains, fruits & vegetables	6	2.00
5	Photovoltaic telecommunication system	4	5.00
6	Solar hydrogen production pilot project	5	46.00
7	Integrated renewable energy community project	4	23.00
8	Installation of a 1MW solar thermal power plant in desert area of Pakistan	1.5	5.00
9	Biogas Plants for meeting domestic fuel and fertilizer needs of rural Areas	4	5.00
10	Improvement and dissemination of 100 improved micro hydropower plants (MHP) in NWFP, FATA, Northern areas of the country.	4	5.00
11	Biomass utilization at community level.	4	5.00
12	Dissemination of 100 wind turbines for water pumping and power generation in the Southern and Coastal Areas.	5	10.00
13	Portable water supply system in remote areas by photovoltaic pumping.	3	1.00
14	Installation of solar garden lights at public places.	2	0.30
15	Installation of solar street lights.	2	0.80
16	Training courses on solar thermal and photovoltaic applications for general public awareness.	2	0.02

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9. Policy, planning and strategy

The major barriers for solar energy development in Pakistan are the initial cost and institutional weaknesses. In view of its long term benefits, including environmental and socio-economic, a policy is needed to promote solar technology for commercial applications, including power generation, in the country. This can be achieved through institutional and policy improvements, following the successful examples of neighboring countries like China, India and Nepal. Solar energy technologies in Pakistan have not been exploited on a large scale for a number of reasons, such as fear of the high cost of solar energy technologies, lack of motivation and incentives, and inadequate demonstration of effective use of the technologies. Recently, there has been an awakening among government circles for the need to use renewable energy technologies to save the environment and improve the socio-economic conditions of people living in remote areas. Accordingly, solar energy has been listed as a high priority area in the 9th Five Year Plan (1998–2003) of the Government of Pakistan. Although reasonable infrastructure already exists in the country, R&D and production levels have been limited due to lack of finances. In

order to promote solar energy in Pakistan, there is a need to take certain drastic measures to provide incentives and funds for its practical demonstration, to convince and educate people and to develop pilot scale activities. These measures are necessary to give a foothold to industrial and commercial ventures in these 21st century technologies.

Some highly recommended measures according to the World Energy Council [5] are as follows:

- Formulate long term strategies to include, progressively, the renewable/solar energy technologies in the national energy policy;
- Provide adequate funds for R&D and for transforming lab-scale products into commercial products;
- Motivate entrepreneurs through policy initiatives such as tax breaks, reduction/exemption from import duties and taxes;
- Provide soft loans/subsidies to the end users;
- Motivate through mass media, exhibition, field demonstration, education and training;
- Encourage installation of solar lights and other appliances on public buildings, parks, streets etc; and
- Provide funds for renewable energy demonstration community projects.

In order to adopt solar energy technologies and make these acceptable for the community, the following further suggestions are made by the authors:

1. Solar energy technologies should gradually replace the existing technologies and the transition should be smooth to allow proper adaptation by the Pakistani people.
2. Solar energy products should be made available at economical rates. To achieve this objective, subsidies should be considered.
3. Adequate funds should be made available for R&D work for the development of these technologies in public and private sector. Students at universities should be encouraged to conduct research projects in renewable energy.
4. Policies must be made to ensure that foreign investors transfer the know-how for fabrication of solar energy devices such as solar cells and its related technologies to Pakistani counterparts.
5. International cooperation should be actively sought for proper training of local manpower.

10. Conclusions

Pakistan has undoubtedly large potential for harnessing solar energy. Due to higher costs involved, the solar photovoltaic option is only suitable for the areas far off from the grid. However, the country as a whole can adapt solar thermal technologies such as solar water heaters and solar cookers, which will allow considerable savings in fossil fuels consumption, and in turn will help in improving the living standards of Pakistani people and environment quality. In particular, it is

envisaged that by increasing the use of solar energy technology, the oil import bill would decrease, which is actually a huge burden on Pakistan's economy. Well-organized and concerted efforts are needed to be taken by the government to promote the use of solar energy and to educate people about its associated benefits.

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